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COMBAT DAMAGE ASSESSMENT TEAM
A-10/GAU-8 LOW ANGLE FIRINGS
VERSUS
INDIVIDUAL SOVIET TANKS
(February - March 1978)

R.H.S. Stolfi

J.E. Clemens

R.R. McEachin

August 1979

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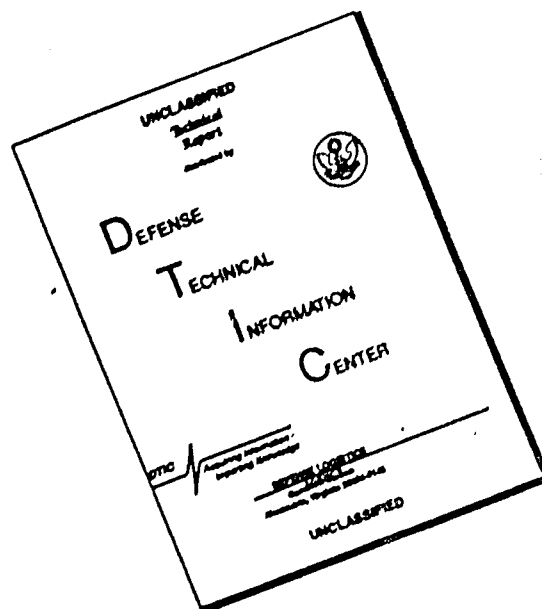
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3. A-10 aircraft	7. gun ammunition lethality									
4. main battle tank (MBT)	8. MBT vulnerability and survivability									
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) <p>This report describes firings of the A-10/GAU-8 weapon system against individual combat loaded Soviet main battle tanks. The pilots making the firing passes attacked at low altitude and corresponding low dive angles simulating movement through a hostile air defense system. Ammunition used in the attacks comprised 30mm armor piercing incendiary rounds, which proved to be effective damage agents against substantial areas of the Soviet T-62 tanks used as targets. The pilots in six successful firing</p>										

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passes (one additional pass resulted in a miss) scored 95 impacts on target, which included 17 perforations through the armored envelope. The six tanks which were impacted received damage physically assessed as ranging from catastrophic in the case of two combat loaded vehicles to negligible in the case of one tank attacked directly from the front.

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COMBAT DAMAGE ASSESSMENT TEAM

**GAU-8 LOW ANGLE FIRINGS
VERSUS INDIVIDUAL SOVIET TANKS
FEBRUARY 1978 - MARCH 1978**

By The

Combat Damage Assessment Committee

**Dr. R. Stolfi, Naval Postgraduate School
Dr. J. Clemens, Battelle Columbus
Mr. R. McEachin, Battelle Columbus**

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**COMBAT DAMAGE ASSESSMENT TEAM
A-10/GAU-8 LOW ANGLE FIRINGS**



INDIVIDUAL SOVIET TANKS

FEBRUARY-MARCH 1978

EXECUTIVE SUMMARY

BY THE COMBAT DAMAGE ASSESSMENT COMMITTEE

CDAC
EXECUTIVE SUMMARY

Under the technical direction of the Combat Damage Assessment Committee (CDAC), the Combat Damage Assessment Team (CDAT) conducted firings of the A-10/GAU-8 weapon system against individual modern main battle tanks (MBTs). The test philosophy was one which emphasized empirical realism and the CDAT used actual Soviet T-62 tanks stowed with 90mm TP ammunition, diesel fuel, lubricating oil, and crew mannikins for the firings. The pilots of the A-10 aircraft used in the test conducted their attacks at low altitudes and low dive angles simulating approach and attack below the altitudes of effective engagement for many opposing air defense networks employing acquisition and fire control radar. The purpose of the test was to evaluate the lethality of the 30mm APIT ammunition of the GAU-8 guns at low aircraft dive angles against realistic MBT targets with the pilots using operational tactics and attack modes.

The Combat Damage Assessment Committee assessed the results of the low angle firings of the A-10 aircraft against the combat loaded T-62 tanks as follows:

1. Attack Parameters: The pilots of the A-10 aircraft attacked individual Soviet T-62 tanks in five missions totalling seven passes against two available combat loaded vehicles which were rehabilitated after each pass. The aircraft were seldom over 200 feet altitude in the missions and dive angles varied from 1.8 - 4.4° for the measured passes. The pilots opened fire at slant ranges between 2768-4402 ft. and ceased fire at ranges between 1587-3055 ft. The burst lengths varied from 120-165 rounds.

2. Weapon Effects: The A-10/GAU-8 weapon systems achieved 93 impacts on six of the seven individual tanks which they attacked (one firing pass resulted in a miss of the target). The ratio of impacts to rounds fired was 0.10. The weapon system achieved 17 perforations of the armored envelopes of the tanks with a ratio of perforations to impacts of 0.18. Many projectiles, which did not perforate armor, severely damaged exterior suspension components of the tanks. The pilots attacked two of the tanks directly from the front with negligible weapon effects and this circumstance should be considered in judging the effectiveness of the system. The pilots attacked five of the tanks from more favorable side and rear aspects and achieved all of the perforations at those attack aspects.

3. Damage Assessment: The A-10/GAU-8 weapon system inflicted three catastrophic kills through projectile and/or fragment effects against stowed ammunition. The weapon system inflicted two additional 100% mobility kills through internal damage to transmissions, fuel tanks and external damage to track, suspension and drive components. One additional tank was fired on and missed and one tank suffered negligible damage from frontal impacts.

4. Test Conditions: Ceiling and visibility were unlimited during the firing and the target tanks were sited in open, flat desert terrain. Dry weather prevailed prior to the test and much dust was created during each firing pass by the projectile impacts. Since the pilots made single passes against individual targets, their accuracy in firing was not considered to have been significantly affected by the immediate dust.

5. Conclusions:

a. The A-10/GAU-8 firings of 17 February - 10 March 1978 show that the system has the accuracy and lethality to immobilize or catastrophically destroy T-62 tanks in attacks at low altitudes and dive angles.

b. The GAU-8 30mm APIT ammunition fired at low dive angles (1.8-4.4°) and substantial open fire ranges (4402-2768 ft.) can perforate the rear and sides of the hull and turrets of the Soviet T-62 tank.

c. The A-10/GAU-8 weapon system can kill Soviet T-62 tanks at low dive angles in a tactical engagement arc of approximately 210° including horizontal attack angles of approximately 75-285°, i.e., both sides as well as the rear of the Soviet tanks.

d. The tests to date suggest that shorter open fire ranges of 3000-2000 feet with shorter bursts of approximately 50-100 rounds will result in higher average numbers of impacts, perforation, and kills than the longer test open fire ranges of approximately 4400-3300 feet and bursts of 120-140 rounds. The above conclusion is based on the observed higher percentages of impacts earlier in the long bursts in the test, greater accuracy of the gun system at closer ranges, and higher terminal velocities of the kinetic energy ammunition at shorter ranges.

e. The achieved damage levels at low dive angles were as effective as those obtained earlier using high angle (25-30°) attack modes during tests conducted in 1975¹. The firings of 17 February - 10 March 1978 physically demonstrate that attacks by the A-10/GAU-8 system at low dive angles are a viable alternative to the higher angle attacks used successfully in previous firings. The overall results of the firings of February and March 1978 are summarized in Table 1.

¹See John E. Clemens, A-10 GAU-8 Lethality Tests Against U. S. and Soviet Armor (University of Dayton, 1977), 88 pp. for the results of the earlier firings.

TABLE I

DAMAGE ASSESSMENT SUMMARY

TESTS OF 17 FEB - 10 MAR 78

Mission/Pass	Target	Slant Range (ft)	Dive Angle (deg)	A-10 Speed (ft/sec)	Attack Aspect (deg)	Rounds Fired (1)	Impacts	Perfs	Impacts Per Rounds Fired	Perfs Total Impacts	Kills
1	1	13	(2)	(2)	180(3)	144	6	1	6/144	1/6	K
2	1	13	4402(5)	2.3	599	180	11	2	11/144	2/11	K
		3055(6)									
2	2	18	3502(5)	1.8	574	90	21	2	21/144	2/21	100% M
		2382(6)									95% F
3	1	18	3735(5)	4.4	636	90	16	1	16/120	1/16	100% M
		2616(6)									60% F
4	1	18	2768(5)	4.5	656	0	0	0	0	0	None
		1587(6)									
4	2	13	3321(5)	3.9	646	155	33	11	33/120	11/32	K
		2221(6)									
5	1	18	(2)	(2)	0(4)	165	7	0	7/165	0/7	None

NOTES: (1) Approx. 2 second burst lengths (2) No Time Space Position Information (TSPI) Available
 (3) Estimated from Pass 2 TSPI data (4) Estimated from Pass 6 TSPI data
 (5) Commence Fire (6) Cease Fire

APPENDIX A
COMBAT DAMAGE ASSESSMENT TEAM
A-10/GAU-8 LOW ANGLE FIRINGS



INDIVIDUAL SOVIET TANKS

FEBRUARY-MARCH 1978

REPORT

BY THE COMBAT DAMAGE ASSESSMENT COMMITTEE

APPENDIX A

THE CDAT GAU-8
LOW ANGLE FIRINGS VERSUS INDIVIDUAL SOVIET TANKS
FEBRUARY 1978 - MARCH 1978

COMBAT DAMAGE ASSESSMENT COMMITTEE (CDAC) REPORT

Dr. R. Stolfi, Naval Postgraduate School
Dr. J. Clemens, Battelle Columbus
Mr. R. McEachin, Battelle Columbus

I. INTRODUCTION AND BACKGROUND

Since February 1978, the Armaments Directorate, A-10 Special Project Office, Wright Patterson Air Force Base, Ohio, has sponsored a series of tests using the A-10/GAU-8 system in air-to-ground engagements of armored targets. These tests have been conducted within the framework of the GAU-8A 30mm Ammunition Lot Acceptance Verification Program (LAVP) - Airborne. The LAVP has the following objectives which apply to the present series of tests:

- (1) To evaluate the performance of existing production lots of GAU-8 ammunition when fired from the air under operational conditions.
- (2) To evaluate the lethality of GAU-8 ammunition against specific threat targets when fired from A-10 aircraft using operational tactics and known launch parameters.

The mission of the A-10 aircraft is to provide close air support for U. S. ground forces against a broad spectrum of targets which can be expected to confront those forces in future conflicts. The most challenging enemy target within the entire spectrum is probably the main battle tank (MBT). From the viewpoint of both numbers and qualities, MBTs have dominated the military landscape in Europe, the Middle East, and the Indian Subcontinent since the Second World War. The MBT with its formidable armor protected firepower, communications, and cross country mobility, and its ability to mass and disperse quickly makes it the most difficult mobile target to defeat on the modern battlefield.

In Central Europe, U. S. and other NATO military units are faced with Soviet and other East European ground forces whose offensive tempo is geared to the mobility, firepower, and protection afforded by the MBT. Western forces hold approximately 6000 MBTs and various other ground and air weapons to resist attack from the East. The problem of defeating hostile MBTs takes on added significance when one considers that potentially hostile forces are estimated to have approximately 19,000 tanks available for the opening stages of a conflict in Central Europe.

The recent USAF firing tests concentrated on attack against the most challenging target that U. S. and other NATO forces would confront in Europe - the main battle tank. The USAF conducted the tests at Nellis Air Force Base, Nevada, between 17 February - 10 March 1978. The tests comprised low angle passes of the Fairchild Republic A-10A aircraft firing 30mm APIT projectiles from the internally mounted GAU-8A cannon against individual Soviet T-62 tanks loaded with ammunition, diesel fuel, lubricating oil, and crew mannikins. The tests were designed to evaluate the low dive angle capabilities of the A-10/GAU-8 weapon system to damage Soviet MBTs. The attack parameters associated with the test

involved low altitude, low angle attacks by aircraft flying at high attack air speeds relative to the maximum performance of the system.

To conduct the present tests, the Armaments Directorate, A-10 Special Project Office, Wright Patterson Air Force Base, Ohio, has coordinated extensively with Headquarters, Tactical Air Command, Langley, Virginia, and the Fighter Weapons Center, Nellis Air Force Base, Nevada. Within the framework of that cooperation, the Armaments Directorate set up a Combat Damage Assessment Team (CDAT), which includes civilian contractors and Nellis Air Force Base range personnel to prepare, execute, and evaluate the present tests and future similar ones. The CDAT is directed by a Combat Damage Assessment Committee (CDAC) which has the authority to influence the technical details of the test and the responsibility for final evaluation of the results. The CDAC consists of the following members:

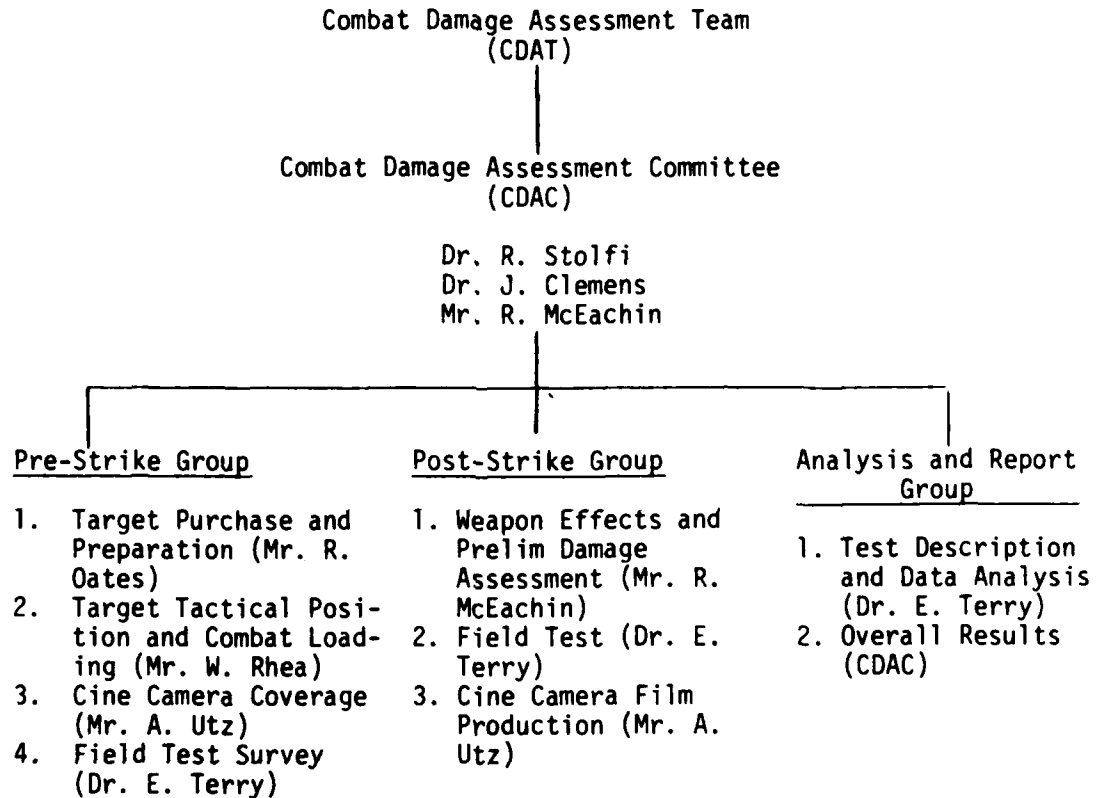
Dr. Russel H. S. Stolfi, Associate Professor, Naval Postgraduate School, Monterey, California (Chairman)
Dr. John E. Clemens, Battelle Memorial Institute, Columbus, Ohio (Member)
Mr. Raymond R. McEachin, Battelle Memorial Institute, Columbus, Ohio (Member)

The mission of the CDAT is to set up, conduct, analyze, and report on firings of the A-10/GAU-8 weapon system which (1) subject the ammunition to conditions adequately simulating actual operations, and (2) allow for a credible assessment of the weapon effects and damage capabilities of the ammunitions. The firings conducted between 17 February - 10 March 1978 subjected the ammunition to the conditions existing in low level attacks by A-10 aircraft against actual combat loaded T-62 tanks. To conduct these firings and similar ones in the future, the CDAT is organized into the functional groups shown in Chart 1.

The chart shows a loose, functional organization in which a Combat Damage Assessment Committee coordinates the activities of a Pre-Strike, Post-Strike, and Analysis and Report Groups. The groups are responsible, in conjunction with the project officer at Nellis Air Force Base, Nevada, for testing the GAU-8 ammunition. The CDAC felt that for the initial airborne firings of February - March 1978, the A-10/GAU-8 system should attack singly at relatively close ranges against systematically oriented combat loaded T-62 tanks. The CDAC oriented the tanks to collect data on engagement effectiveness against tanks presenting frontal, side, and rear aspects to the attacking aircraft.

CHART NUMBER 1

Organization of the Combat Damage Assessment Team



II. TEST PHILOSOPHY AND EXPERIMENTAL SETUP

The firing tests of 1978 had as their overall purpose to evaluate the performance of GAU-8 ammunition when fired from the air under operational conditions and to determine its lethality against specific threat targets. The test philosophy was one which emphasized physically demonstrable results achieved under circumstances simulating combat as closely as practicable. The Armaments Directorate, A-10 Special Project Office, in turn, would use the demonstrated results to verify the effectiveness of existing lots of ammunition and effect the appropriate improvements in ammunition to be produced in the future. Within the overall framework of empirical reality, the Directorate more specifically sought a test philosophy which would produce credible data and accurate conclusions about the effectiveness of GAU-8 ammunition fired at low dive angles at Soviet tanks. To generate credible data, the Directorate decided to use a technique of destructive testing of actual tank targets proceeding from firings at individual tanks through firings at tactically arrayed formations of Soviet or simulated Soviet tanks.

The experimental setup for the firings of 17 February - 10 March involved the use of two T-62 tanks which were fired at as individual targets in single passes by attacking aircraft. Earlier ground firing tests in November 1977, had been conducted as basic data collection efforts to judge the lethality of the GAU-8 ammunition against the vertical side surfaces of the hull of the Soviet T-62 tanks and side surfaces of the turrets which would be exposed to impact by projectiles arriving from A-10 aircraft attacking at low dive angles. The November 1977 firings clearly showed the sensitivity of the Soviet tanks to perforation and damaging hits when presented in side and rear aspect to aircraft attacking from open fire engagement ranges of approximately 4000 feet and less. The impressive weapon effects of the early test encouraged the CDAT to take a decisive step toward operational realism. The CDAT and the Armaments Directorate agreed that firings against individual Soviet tanks systematically sited to present varying aspects and armored surfaces would (1) yield additional basic data, and (2) involve operational conditions of actual aircraft flight which would result in a superior evaluation of the 30mm APIT projectiles being fired.

Warsaw Pact forces in Europe would probably employ several different MBT models as part of an attack into West Germany. The elite Group of Soviet Forces, Germany, would employ a mix of T-72, T-64 and T-62 tanks, while the remaining Pact countries would probably employ a mix of T-62 and the aging T-55 tanks. At present, the potential attacking Pact forces in Central Europe probably have a majority of T-62 tanks, and a significant, rapidly increasing number of T-64 and T-72 vehicles. The most effective targets to represent Soviet tanks would be either T-64 or T-72 tanks. The U. S. has not been able to acquire either a T-64 or T-72 tank, however a T-62 tank was available and was used as a target for the destructive testing.

The Soviet T-62A tank (Fig. 1) represents the greatest ground threat to U.S. forces in Europe in terms of numbers available to the Soviet units which would initially be committed to combat in a future war in Europe. The performance characteristics of this tank can be found in several classified and unclassified references.

Two T-62 tanks were available for use as targets. These tanks were rehabilitated to a level suitable to the collection and assessment of weapons effects and lethality data. The rehabilitation required that the on-board vulnerability critical components be simulated in order to meet test requirements for a "combat configured" tank. The critical components were considered to be stowed ammunition, fuel and oil, and crew personnel. These items were simulated as follows:

Personnel -- Mannikins constructed of 1/2" plywood and articulated at the joints to allow a reasonable representation of personnel in a combat posture.

Fuel Tanks -- Five-gallon military type gas cans filled with D-2 diesel fuel.

Ammunition -- U.S. Cartridge, 90mm, TP-T.

Oil Tanks -- Five-gallon military type liquid containers filled with engine-type lubricating oil.

The ammunition, oil, and fuel were placed within the tank hull in locations approximating as closely as possible their original position. Figure 2 is a sketch showing the location of fuel and ammunition. The mannequins were placed at crew stations in positions approximating the combat posture of crew personnel in closed hatch operations.

Figures 3 and 4 are photographs of the simulated ammunition and fuel stowage in the hull and turret. For Mission 1, the racks shown for stacking ammunition (notched 2" x 6" boards) were not available, and the appropriate number of rounds were stacked on ammunition boxes. For the remaining Missions 2-5, the CDAT used the wooden racks shown in Fig. 3 and 4.

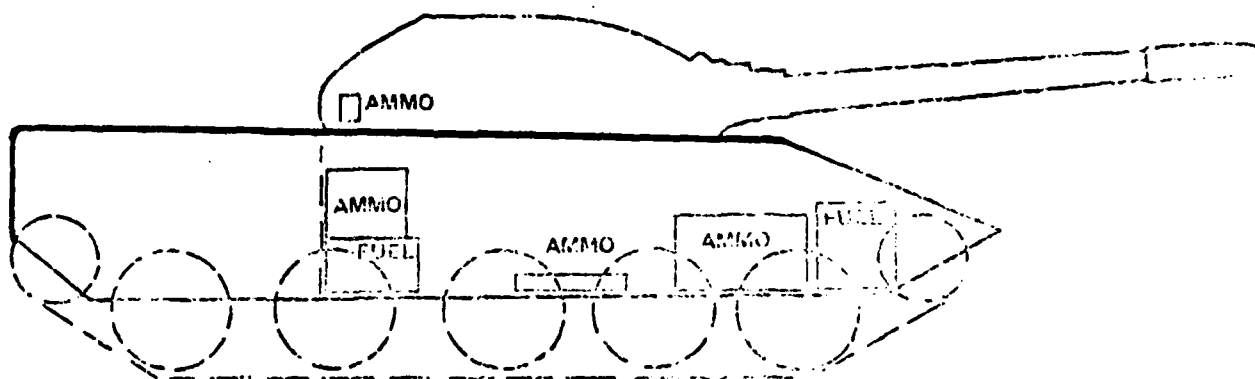
The precise configuration of targets prior to each mission is presented in the Low Angle Strafe Demonstration Test Report, which was completed by the pre-strike field test survey group at Burlington, Vermont, after the completion of the firings. The targets were suitable for collection and assessment of weapons effects and lethality data of the type which represented the main thrust of the ammunition firing.

It can be asserted with a high degree of confidence that:

- The armor of the target tanks was intact for test purposes (only one projectile penetrated through previously made holes) and provided a fair test of the penetrating capabilities of GAU-8/A projectiles under the existing conditions.
- Given a perforation of the armored envelope, the simulations provided the means to demonstrate that the GAU-8/A projectile retained or did not retain sufficient velocity to damage critical components behind the plate through dynamic interactions between critical sensitive components and the projectile itself or through the creation of back spalling.



Fig 1. Left Front View of T-62 Tank



AMMUNITION: U.S. 90-MM TP-7
 FUEL: D-2 DIESEL IN 3/11 FULL 5 GAL GALS

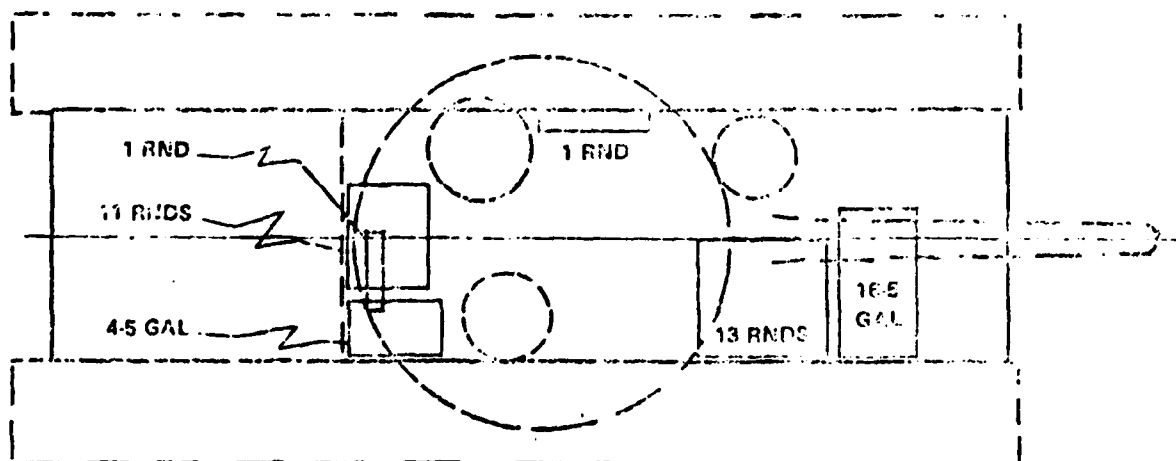


Fig 2. Locations of Fuel and Ammunition in Target Tanks

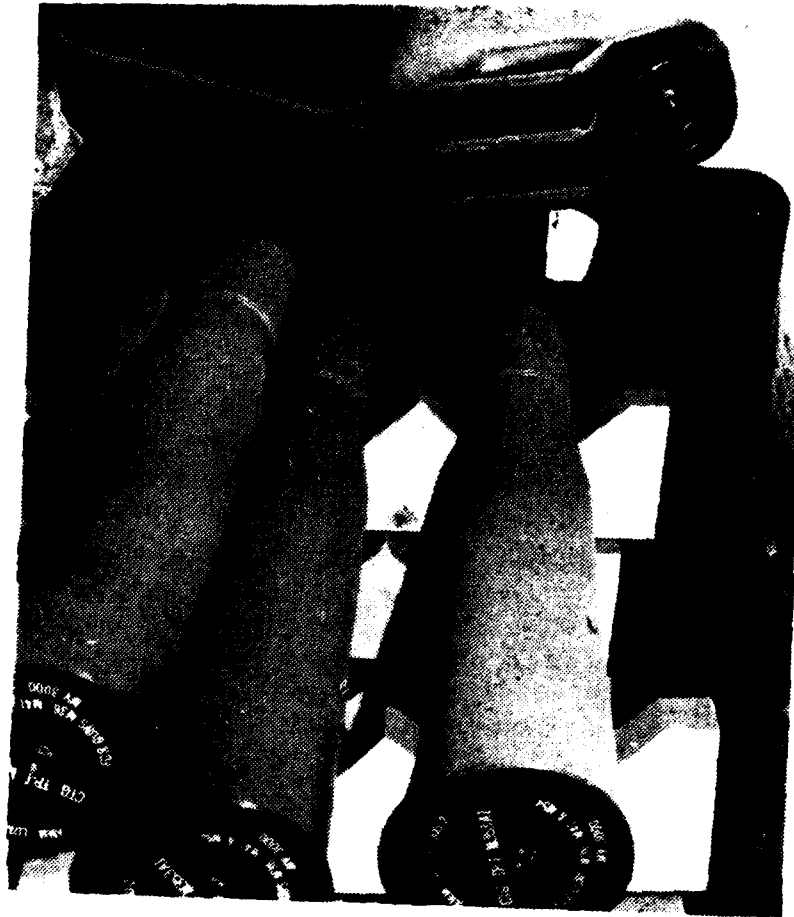


Fig 3. Simulated Bow Racks and Fuel Tank



Fig 4. Simulated Fuel Tank and Rear Fighting Compartment Ammunition Stowage

III. DEFINITIONS

The terms used in Section IV - WEAPON EFFECTS AND DAMAGE ASSESSMENT, are defined below:

IMPACT -- Any evidence of a projectile strike against any portion of the target. Ground ricochets striking the target were classified as "impacts".

PERFORATION -- Any rupture of the armored envelope caused by an impacting projectile which results in behind-the-plate effects by the projectile or spall fragments. A perforation can occur only when the armor is impacted. The word "Perforation" was deliberately selected to avoid the ambiguities which may occur through use of the word "penetration".

HIT -- Any impact not classified as a perforation.

MOBILITY KILL (M-KILL) -- Loss of tactical mobility resulting from damage which cannot be repaired by the crew on the battlefield. A tank is considered to have sustained an M-Kill when it is no longer capable of executing controlled movement on the battlefield. Mobility is DEGRADED when a tank can no longer maintain its position in the formation of which it is a part.

FIREPOWER KILL (F-KILL) -- Loss of tactical firepower resulting from damage which cannot be repaired by the crew on the battlefield. A tank is considered to have sustained an F-Kill when it is incapable of delivering controlled fire from its main armament. Firepower is DEGRADED when a tank can no longer maintain its "normal" rate-of-fire, velocity, accuracy, time to shift targets, etc.

CATASTROPHIC KILL (K-KILL) -- A tank is considered to have sustained a K-Kill when both an M-Kill and a F-Kill have occurred as the result of killing fires and explosions from ignited fuel and/or ammunition. A tank which has suffered a K-Kill is considered not to be economically repairable, and by U.S. standards, would be abandoned on the battlefield.

ATTACK AZIMUTH -- The angle of approach of the aircraft with respect to the orientation of the target with 0° representing the front of the tank (gun forward) and 180° representing the rear of the tank.

IV. WEAPON EFFECTS AND DAMAGE ASSESSMENT

The test series consisted of five test missions which involved seven aircraft passes against two T-62 tank targets. Hits were scored on each pass except one (Mission 4, Target 18), resulting in a total of 18 projectile perforations into the armored envelope out of 104 impacts. A total of 957 rounds was expended during the test. These data are summarized in Table 1 for ready reference.

TABLE II
WEAPON EFFECTS SUMMARY

Mission Number	TARGET 13 (T-62 TANK)				TARGET 18 (T-62 TANK)			
	Misses	Hits	Perfs	Total Fired	Misses	Hits	Perfs	Total Fired
1	138	5	1	144	-	-	-	-
2	133	9	2	144	123	19	2	144
3	-	-	-	-	104	15	1	120
4	88	22	11	120	120	-	-	120
5	-	-	-	-	158	7	0	165

The CDAT, Post Strike Group, collected data on site as soon as possible after each mission. This included range, aircraft, ammunition, gun, and target data and was documented to the extent possible by gun, phototheodolite, and remote ground cameras. These data have been collated, analyzed, and published by the Analysis and Report Group led by Dr. E. R. Terry and published in Gravois, Graham, Neuer, and Gadecki; Final Report on the Results of the Nellis A-10A Low Angle Strafe Demonstration Tests Conducted During the Period of 17 February - 10 March 1978 (General Electric, Burlington, Vermont, 21 Sep 1978), pp 273.

The Combat Damage Assessment Committee (CDAC) through the CDAT was responsible for assessing the damage resulting from each mission and assigning a kill factor according to the terms referenced in Section III. This damage was assessed based on observation of the tests, field notes (data sheets) recorded on-site, study of the photography, de-briefings of the test pilots (66th Fighter Weapons Squadron), and the report referenced above. A summary of the assessments is shown in Table 2.

TABLE III
DAMAGE ASSESSMENT SUMMARY

MISSION DATA			KILL ASSESSMENT		
Mission Number	Target Number	Attack ¹⁾ Aspect	M-Kill (Mobility)	F-Kill (Firepower)	K-Kill (Catastrophic)
1	13	180 ⁰	--	--	100%
2	13	180 ⁰	--	--	100%
	18	90 ⁰	100%	95%	--
3	18	90 ⁰	100%	60%	--
4	13	155 ⁰	--	--	100%
	18	0 ⁰	Not assessed--no projectile impacts on target.		
5 ²⁾	18	0 ⁰	No significant damage.		

1) Planned attack aspect.

2) Mission 5 was essentially a repeat of the 0⁰ attack azimuth of Mission 4.

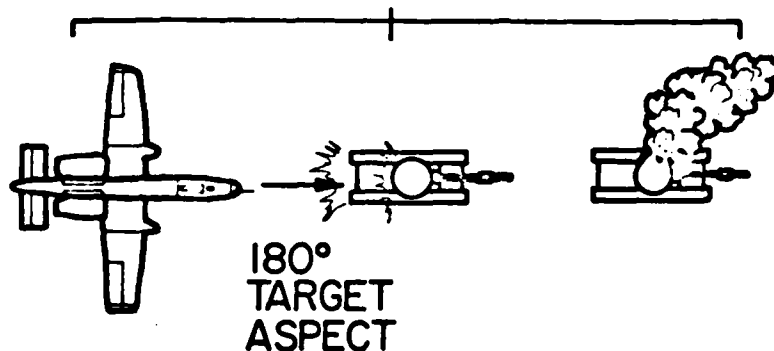
The damage sustained by each target and the rationale behind the above assessments are discussed below on a mission-by-mission basis:

Mission 1, Target 13, 17 February 1978 (See Illustration 1)

This target was assessed as an immediate K-Kill resulting from a perforation (impact No. 1) of the rear turret armor (Fig. 5). The most likely cause of the catastrophic damage was an internal explosion which occurred approximately 0.39 seconds into the cannon burst fired against the tank. The location of the strike (Fig. 6) indicates that the most probable cause of the explosion was the impact of the perforating projectile, or spall fragments, against a single round of ammunition stowed slightly right of center in the rear of the turret just above the turret ring (see Fig. 2). The target was impacted by five other projectiles which caused insignificant damage and made no contribution to the assessed K-Kill.

ILLUSTRATION 1

A-10/GAU-8 LOW ANGLE FIRINGS
VERSUS INDIVIDUAL SOVIET TANKS
(MISSION 1, PASS 1 VS TANK 13)
(17 FEB 78)



① A/C PARAMETERS¹

- SPEED
- DIVE ANGLE
- OPEN FIRE
- CEASE FIRE
- 144 RDS FIRED

② GAU-8 WPN EFFECTS

- 144 RDS FIRED
- 6 IMPACTS
- 1 PERFORATION
- RATIO
IMPACTS / RDS 0.04
- RATIO
PERFS / IMPACTS 0.17

③ DAMAGE ASSESSMENT

- K-KILL
- INTERNAL
EXPLOSIONS
AND FIRE
- RESULTING
FROM SINGLE
REAR TURRET
PERFORATION

I NO TSPI DATA WERE AVAILABLE FOR
MISSION 1, PASS 1



Fig 5. Location of Strike, Impact 1, Mission 1, Target 13



Fig. 6. Close-up view of Impact 1, Mission 1, Target 13
(NOTE: The rectangular hole to the right
of the perforation was occasioned by removal
of the armor for hardness testing. The patch
over the hole was blown outward by the inter-
nal explosion and showed no evidence of other
impacts.)

Mission 2, Target 13, 24 February 1978 (See Illustration 2)

This target was assessed as an immediate K-Kill, resulting from a single perforation of the rear turret armor (Fig. 7). The most likely cause of the kill was an internal explosion which occurred approximately .62 seconds into the burst, probably occasioned by perforation of the armor from impact 1, which occurred .29 seconds into the burst. The location of the strike indicates that the most probable cause of the explosion was impact of the penetrating projectile, or spall fragments, into a single round of ammunition stowed in the rear of the turret (see Fig. 2). The armored envelope of this target was perforated by two other projectiles, impact 5 (Fig. 8) and impact 6 (Fig. 9).

Impact 5 completely penetrated an 8" x 8" timber (used to simulate a deditching log) and perforated the right transmission inspection plate (Fig. 10). The projectile damaged the fan housing and flange causing a 100 percent loss of function to the cooling fan. In the absence of a K-Kill, this damage alone would have resulted in an interdiction type mobility kill occasioned by engine overheating.

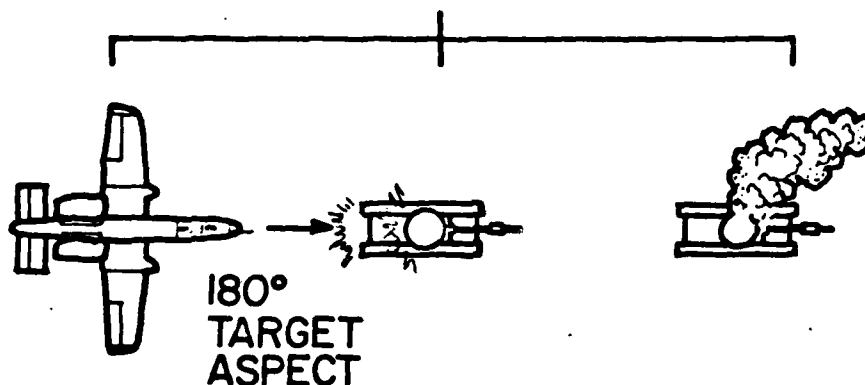
Impact 6 perforated the left rear engine grille and grille cover with no behind plate effects. The trajectory (Fig. 9) indicated that the projectile continued to impact and dislodge an expedient honeycomb patch over a rectangular hole in the rear of the turret where armor had been removed for analysis (Fig. 11). It was the judgment of the on-site CDAT team that this projectile probably would not have perforated clean armor but if it had, would probably have resulted in a K-Kill due to possible impact on the round of ammunition stowed in the rear of the turret (see Fig. 2). The ambiguities associated with this judgment were resolved by film analysis which showed that the perforation of the turret (Impact 1, Fig. 7), and the internal explosion, occurred prior to impact 6 on the engine grille cover.

Significant damage was caused by one additional impact (Impact 11, Fig. 12) which penetrated into the right track drive sprocket, cracking the hub and causing loss of oil and severe damage to the bearings. In the absence of a K-Kill, this damage alone was sufficient to cause a 100 percent mobility kill. However, the reader should be cautioned that the track, which would have shielded the sprocket from this impact, was not in place. If it had been, different results may have been recorded.

The target was impacted by eleven other projectiles which caused insignificant damage and made no contribution to the assessed kill.

ILLUSTRATION 2

A-10/GAU-8 LOW ANGLE FIRINGS
VERSUS INDIVIDUAL SOVIET TANKS
(MISSION 2, PASS 1 VS TANK 13)
(24 FEB 78)



① A/C PARAMETERS

- 348 KNOTS
- 23° DIVE ANGLE
- 4402 FT. OPEN FIRE
- 3055 FT. CEASE FIRE
- 144 RDS FIRED

② GAU-8 V/PN EFFECTS

- 144 RDS FIRED
- 11 IMPACTS
- 2 PERFORATIONS
- RATIO IMPACTS/RDS 0.08
- RATIO PERFS/IMPACTS 0.18

③ DAMAGE ASSESSMENTS

- K - KILL
- INTERNAL EXPLOSIONS AND FIRE
- RESULTING FROM SINGLE REAR TURRET PERFORATION

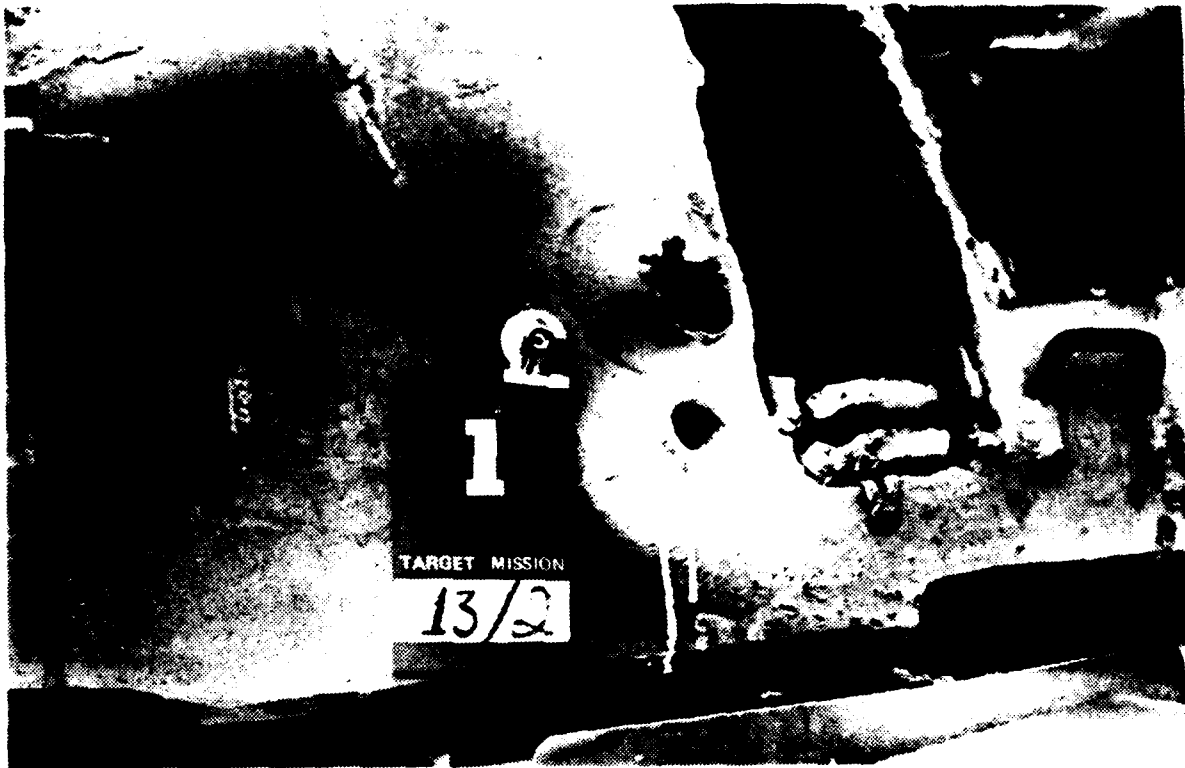


Fig 7. Location of Strike, Impact 1, Mission 2, Target 13



Fig 8. Location of Strike, Impact 5, Mission 2, Target 13



Fig 9. Location of Strike, Impact 6, Mission 2, Target 13

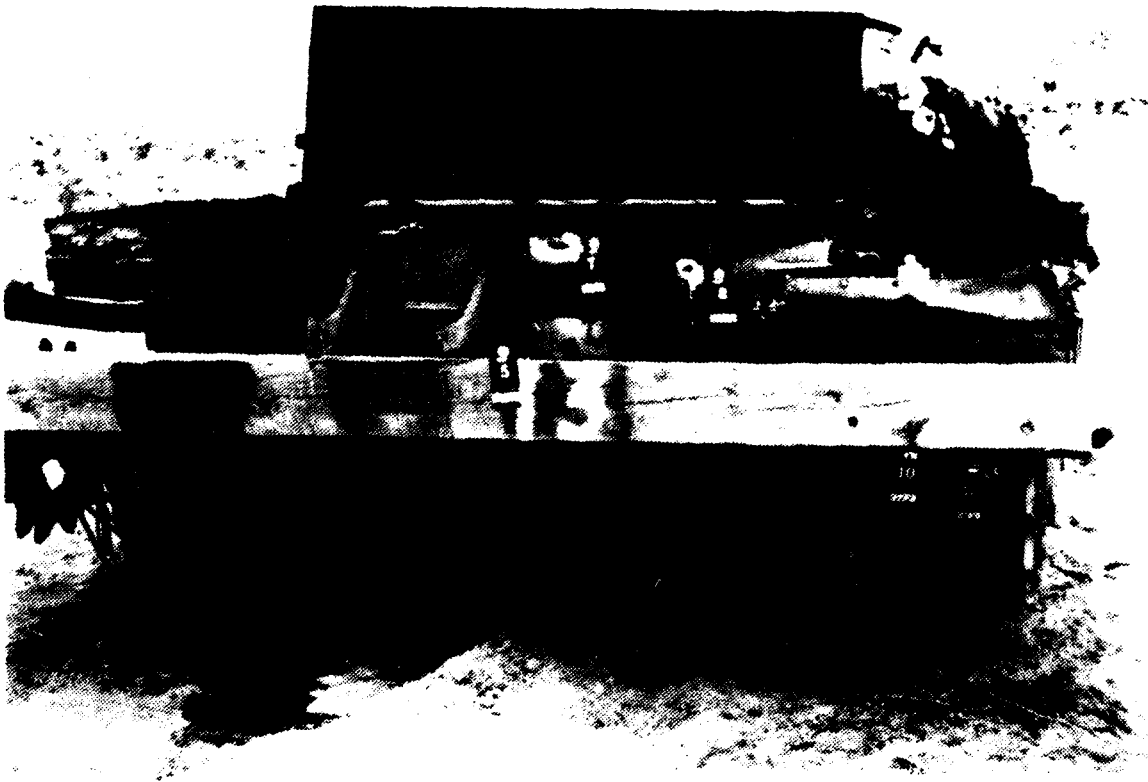


Fig 10. Location of Strike, Impact 5, Mission 2, Target 13



Fig 11. Location of Honeycomb Patch Dislodged by Impact 6



Fig 12. Damage to Right Track Drive Sprocket
Caused by Impact 11 (Mission 2, Target 13)

Mission 2, Target 18, 24 February 1978 (See Illustration 3)

This target was impacted by 21 projectiles of which four caused significant damage. These impacts (numbers 5, 8, 9 and 17) are shown in Fig. 13.

Impact number five perforated the loader's periscope housing (Fig. 14). The projectile and/or spall fragments continued through the fighting compartment to the opposite side of the turret and damaged two mannikins representing the gunner and tank commander. The mannikin at the gunner's station received projectile and/or spall damage in the left shoulder area, and to the right side of the head as shown in Fig. 15 and was assessed as killed in action (KIA). The mannikin representing the tank commander (Fig. 16) was damaged in the left shoulder area and was assessed as wounded in action (WIA). Based on these two casualties, an F-Kill of 95 percent was assessed.

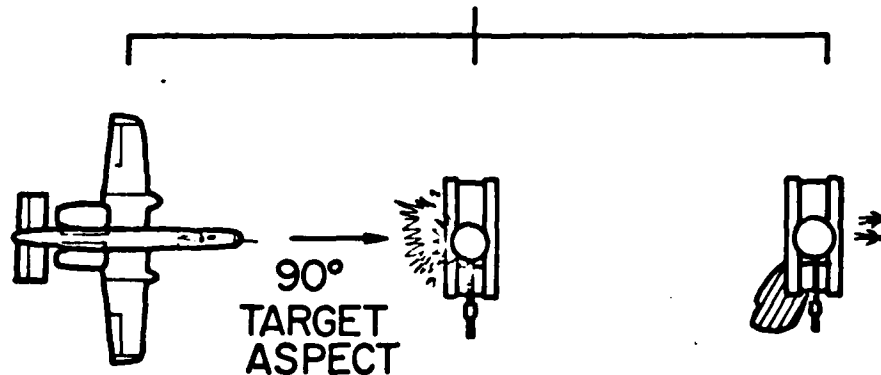
Impact 17 (Fig. 17) perforated the right front side hull armor immediately in front of the number 2 road wheel and ruptured five of the 16 five-gallon fuel cans simulating the bow fuel tank. Figs. 18 through 22 show spall fragment perforations in the fuel cans. A mobility kill was assessed based on a judgment by the CDAT that a ruptured bow fuel tank, together with two crew casualties, would render the tank ineffective for combat. The tank was accorded the capability of moving a short distance to a covered and/or concealed position, or to a maintenance area, for repairs.

Impacts 8 and 9 (Figs. 23 and 24 respectively) penetrated the right front external fender mounted fuel tank causing a 100 percent loss of function. These impacts were assessed as contributing to the mobility kill.

The target was impacted by 17 other projectiles which caused insignificant damage and made no contribution to the assessed kill.

ILLUSTRATION 3

A-10/GAU-8 LOW ANGLE FIRINGS
VERSUS INDIVIDUAL SOVIET TANKS
(MISSION 2, PASS 2 VS TANK 18)
(24 FEB 78)



① A/C PARAMETERS

- 340 KNOTS
- 1.83° DIVE ANGLE
- 3502 FT OPEN FIRE
- 2382 FT CEASE FIRE
- 144 RDS FIRED

② GAU-8 WPN EFFECTS

- 144 RDS FIRED
- 21 IMPACTS
- 2 PERFORATIONS
- RATIO
IMPACTS/RDS 0.15
- RATIO
PERFS/IMPACTS 0.10

③ DAMAGE EFFECTS

- 100% M-KILL
- 0.95 % F-KILL
- RESULTING
FROM GUNNER
KIA TC WIA
AND FUEL TANK
DAMAGE

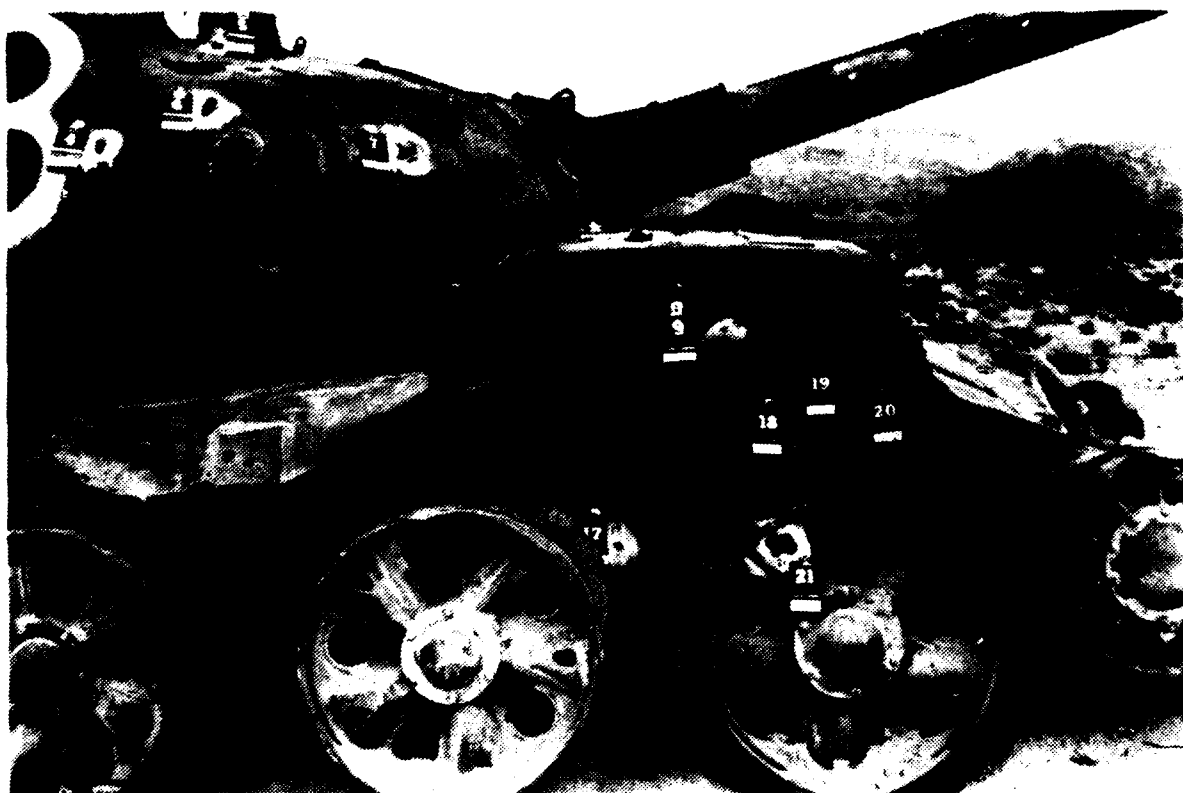


Fig 13. Location of Significant Impacts, Mission 2, Target 18



Fig 14. Close-up View of Perforation Through Loader's Periscope Housing, Mission 2, Target 18



Fig 15. Projectile and/or Spall Damage to Mannikin
at Gunner's Station (Impact 5, Mission 2,
Target 18)



Fig 16. Projectile and/or Spall Damage to Mannikin
at Commander's Station (Impact 5, Mission 2,
Target 18)

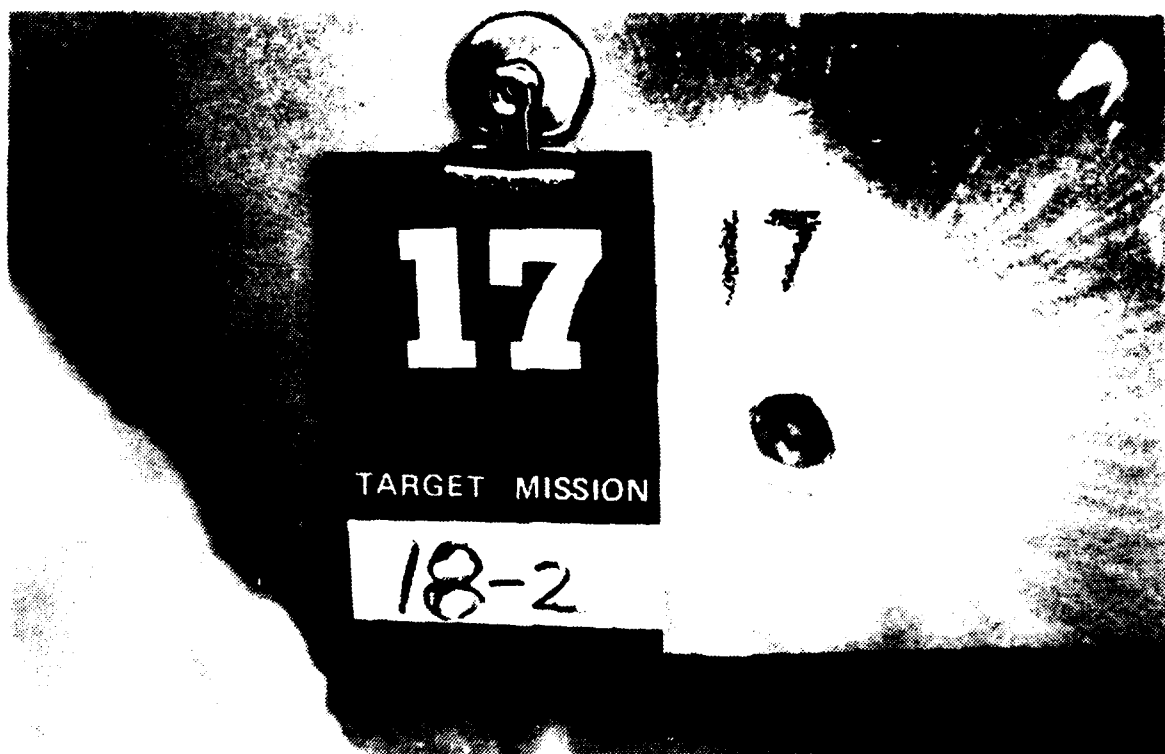


Fig 17. Perforation of Right Side Hull Armor
(Part of Projectile Remains in Hole),
Mission 2, Target 18



Fig 18. Perforation of Fuel Can Simulating
Bow Fuel Tank, Impact 17, Mission 2,
Target 18 (NOTE: This impact is mis-
numbered and should read 17.)



Fig 19. Perforation of Fuel Can Simulating Bow
Fuel Tank, Impact 17, Mission 2, Target 18
(NOTE: This impact is mis-numbered and
should read 17.)



Fig 20. Perforation of Fuel Can Simulating Bow Fuel Tank, Impact 17, Mission 2, Target 18 (NOTE: This impact is mis-numbered and should read 17.)



Fig 21. Perforation of Fuel Can Simulating Bow Fuel Tank, Impact 17, Mission 2, Target 18 (NOTE: This impact is mis-numbered and should read 17.)



Fig 22. Perforation of Fuel Can Simulating Bow Fuel Tank, Impact 17, Mission 2, Target 18 (NOTE: This impact is mis-numbered and should read 17.)

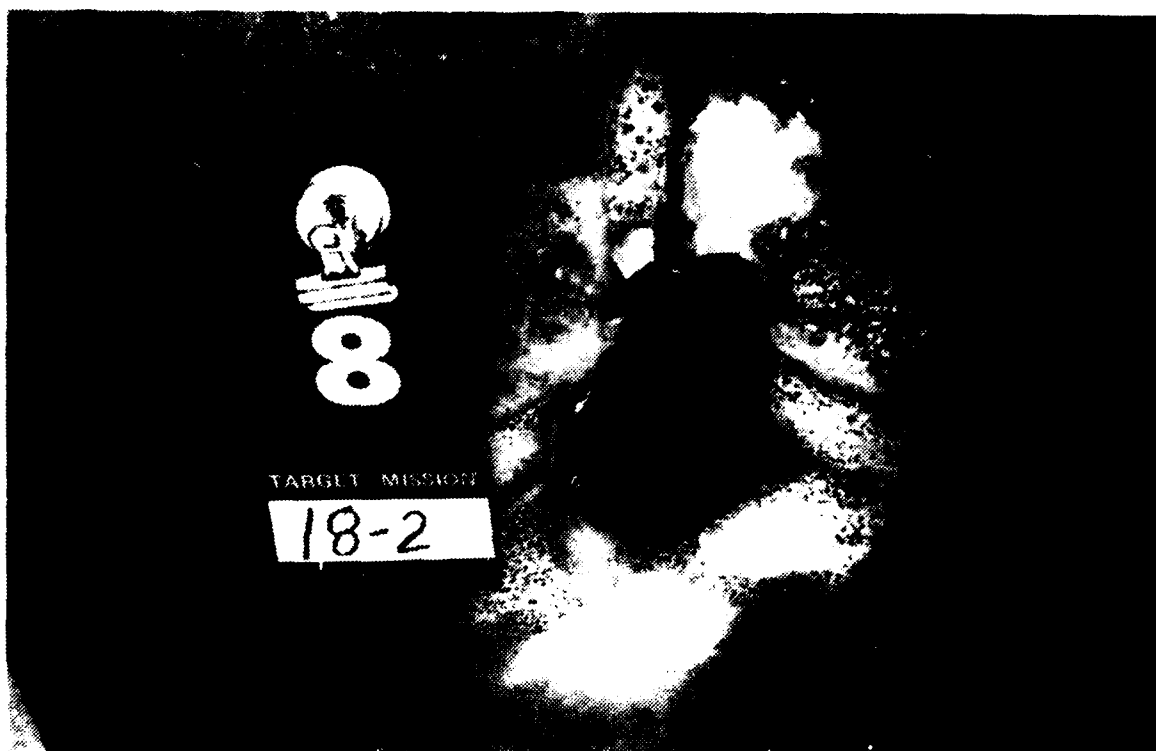


Fig 23. Perforation of External Fuel Tank by
Impact 3, Mission 2, Target 18



Fig 24. Perforation of External Fuel Tank
by Impact 9, Mission 2, Target 18

Mission 3, Target 18, 2 March 1978 (See Illustration 4)

This target was impacted by 16 projectiles, resulting in one perforation and seven other hits causing significant firepower and mobility related damage.

Impact 2 (Fig. 25) perforated the right side hull armor just above the number four road wheel. Projectile and/or spall fragments damaged the left hand and thigh area of the mannequin at the tank commander's station (Fig. 26), a round of ammunition in the fighting compartment stowage area (Fig. 27), and a round of ammunition in the bow storage area (Fig. 28). The tank commander was assessed a casualty (WIA) and a 50 percent F-Kill assigned. No contribution to the kill was assessed due to the fragment damaged ammunition; however, the damage was interesting because it was the widest distribution of fairly large fragments noted in this series of tests.

Impact 15 (Fig. 29) penetrated one wall of the gun tube and was assessed as a 10 percent contribution to the F-Kill. This assessment was based on tactical considerations and the CDAT's perceptions of crew attitudes based on damage to the gun tube alone. It was the CDAT's judgment that the crew would avoid firing chemical energy type rounds such as high explosive anti-tank munitions (HEAT) due to the possibility of premature functioning of the projectile due to gun tube damage. However, it was also considered that during an active engagement against ground targets dangerous to tanks they could and probably would continue to fire kinetic energy (armor piercing) rounds with some loss in accuracy and range which could be compensated for to some extent by gunnery techniques.

A 100 percent M-Kill was assessed due to the following damage:

Impact 3 (Fig. 30) -- Spall from impact on the intermediate track cover perforated the right rear externally mounted fuel cell causing a 100 percent loss of function to the fuel cell.

Impact 10 (Fig. 31) -- Penetrated hub of right No. 1 road wheel causing 100 percent loss of function of the road wheel.

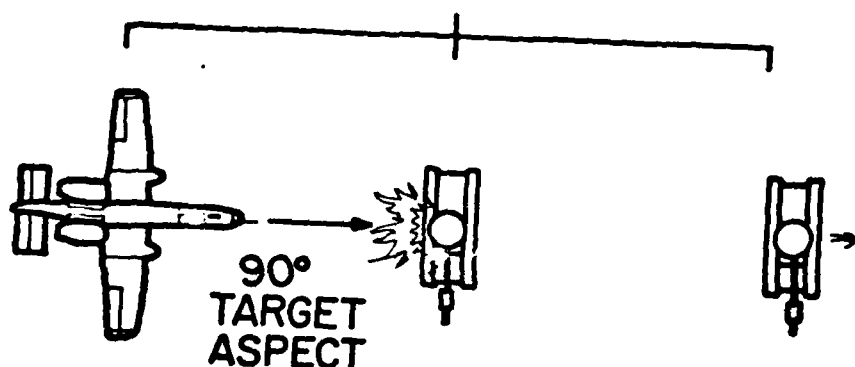
Impacts 11, 12, 13 and 14 (Fig. 32) -- Penetrated or damaged the right idler wheel. Impacts 11 and 13 both caused damage sufficient to result in a 100 percent loss of function to the idler wheel. Impact 12 split the idler wheel rim sufficiently to cause a 10 percent contribution to an M-Kill if considered alone. Impact 14 impacted the idler wheel rim causing negligible damage; however, the track was not in place. If the track had been in place it would have been damaged to an indeterminable extent.

The target was impacted by eight other projectiles which caused insignificant damage and made no contribution to the assessed kill, which overall was assessed as:

Mission 3, Target 18
2 March 1978 Assessment

M-Kill - 100%
F-Kill - 60%

ILLUSTRATION 4
A-10/GAU-8 LOW ANGLE FIRINGS
VERSUS INDIVIDUAL SOVIET TANKS
(MISSION 3, PASS 1 VS TANK 18)
(2 MARCH 78)



① A/C PARAMETERS

- 377 KNOTS
- 4.41° DIVE ANGLE
- 3735 FT. OPEN FIRE
- 2616 FT. CEASE FIRE
- 120 RDS FIRED

② GAU-8 WPN EFFECTS

- 120 RDS FIRED
- 16 IMPACTS
- 1 PERFORATION
- RATIO
IMPACTS/RDS 0.13
- RATIO
PERFS/IMPACTS 0.06

③ DAMAGE ASSESSMENTS

- 100% M-KILL
- 60% F-KILL
- RESULTING FROM
TANK CDR VIA
GUN TUBE PERF
AND SUSPENSION
DAMAGE

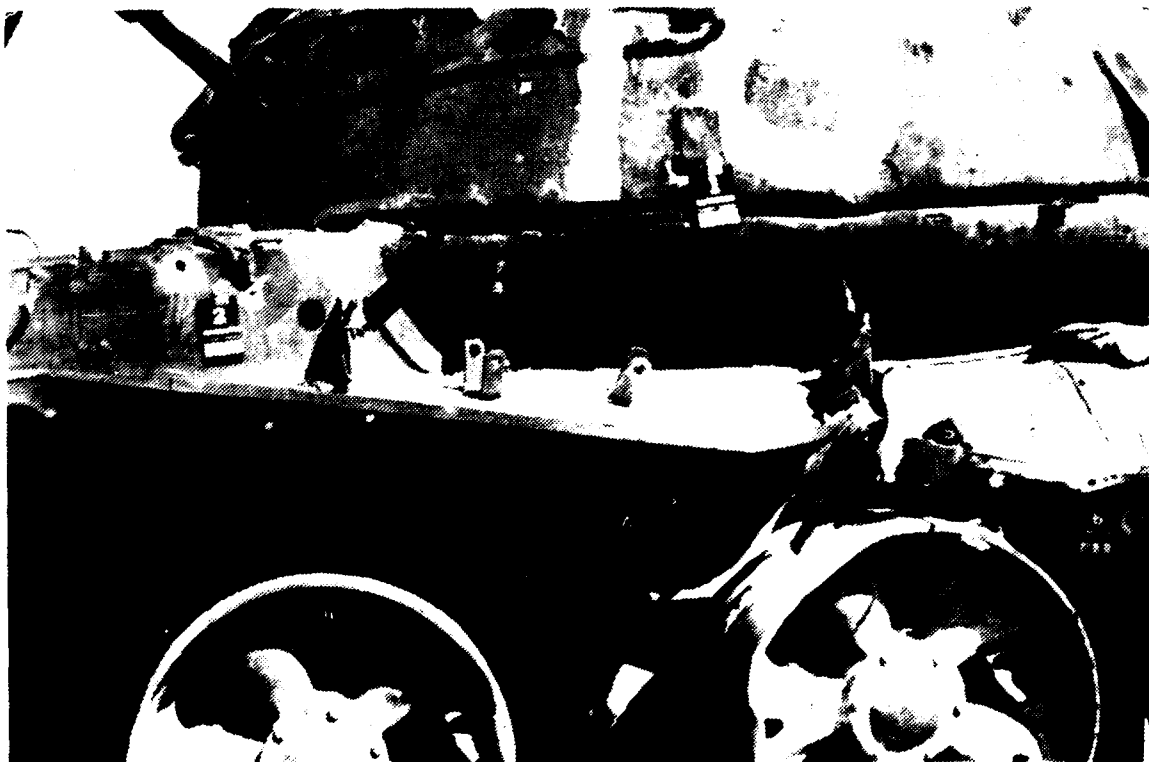


Fig 25. Location of Strike, Impact 2, Mission 3,
Target 18

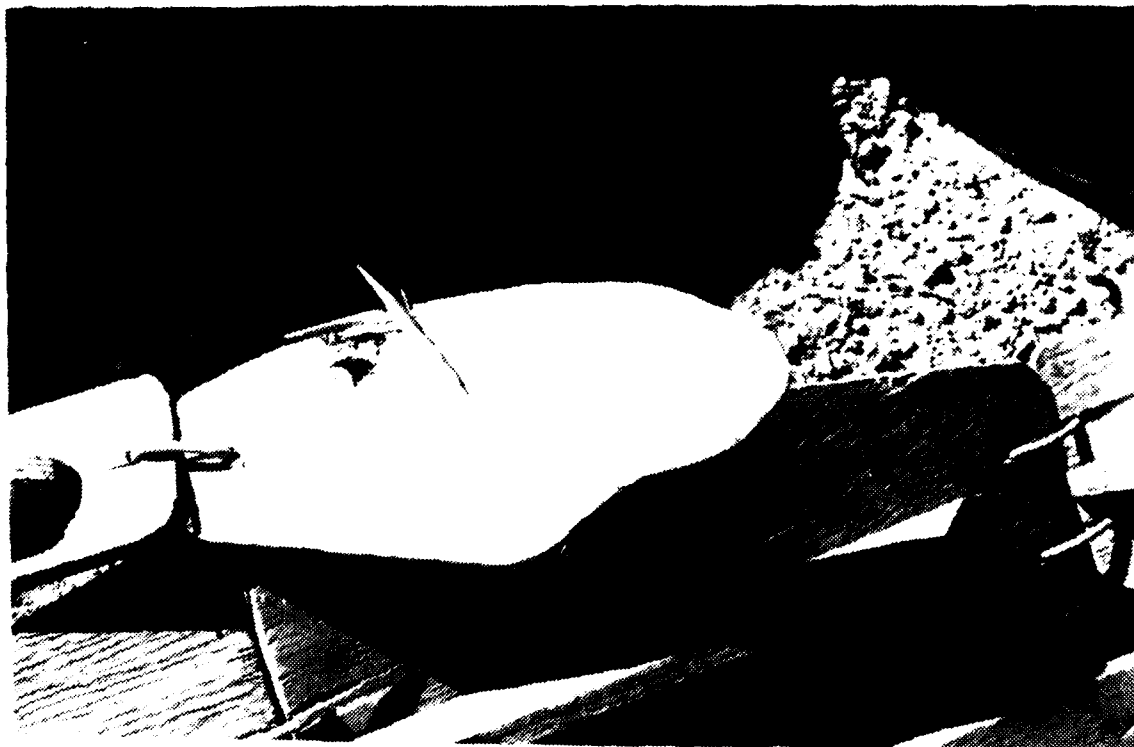


Fig 26. Damaged Left Hand and Thigh Area of
Mannikin at Commander's Station
(Impact 2, Mission 3, Target 18)

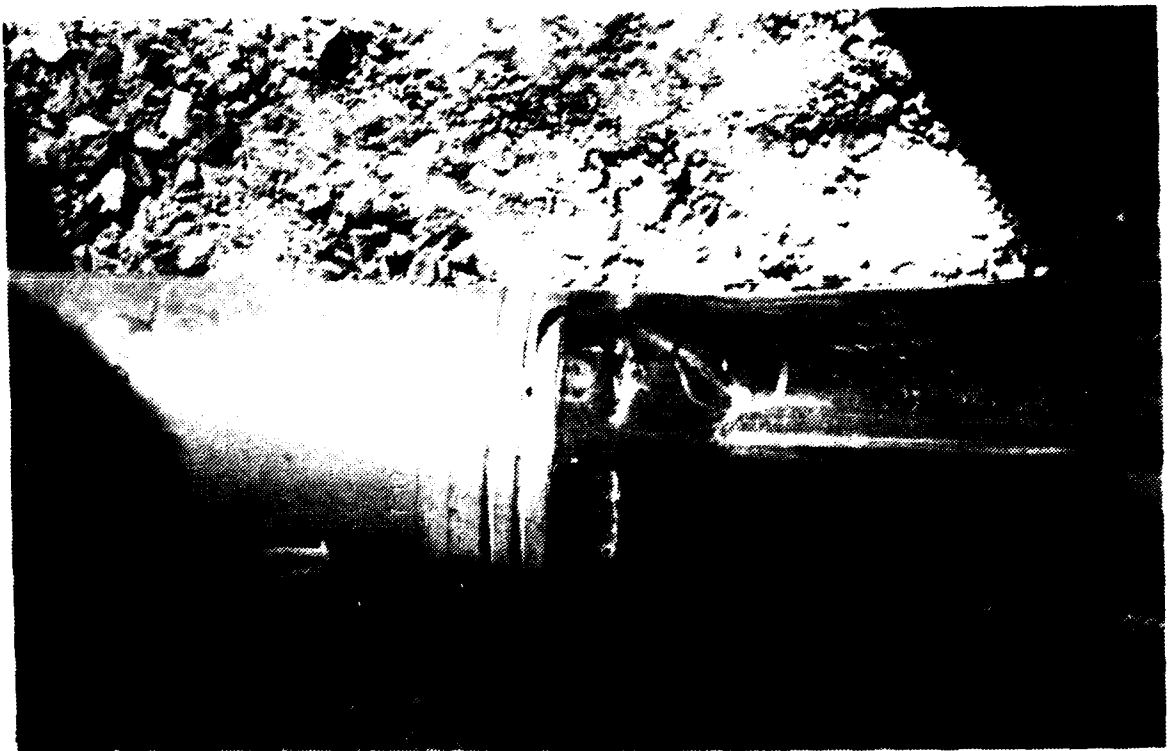


Fig 27. Fragment Damage to Round of Ammunition
in Fighting Compartment Stowage Area
(Impact 2, Mission 3, Target 18)



Fig 28. Fragment Damage to Round of Ammunition
in Bow Stowage Area (Impact 2, Mission 3,
Target 18)



Fig 29. Penetrated Wall of Gun Tube
Impact 15, Mission 3, Target 18

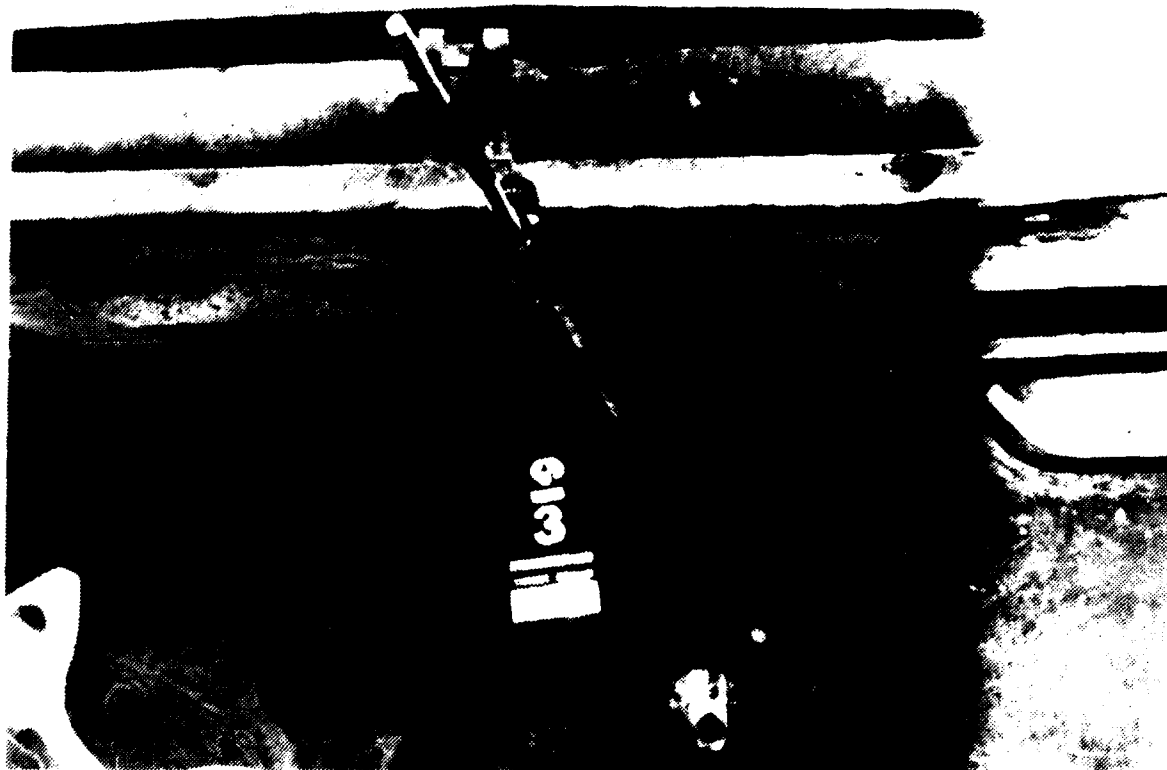


Fig 30. Impact 3, Mission 3, Target 18 Causing Spalling
Which Perforated the Right Rear Externally Mounted
Fuel Cell



Fig 31. Impact 10, Mission 3, Target 18
Showing Damage to Right No. 1
Road Wheel

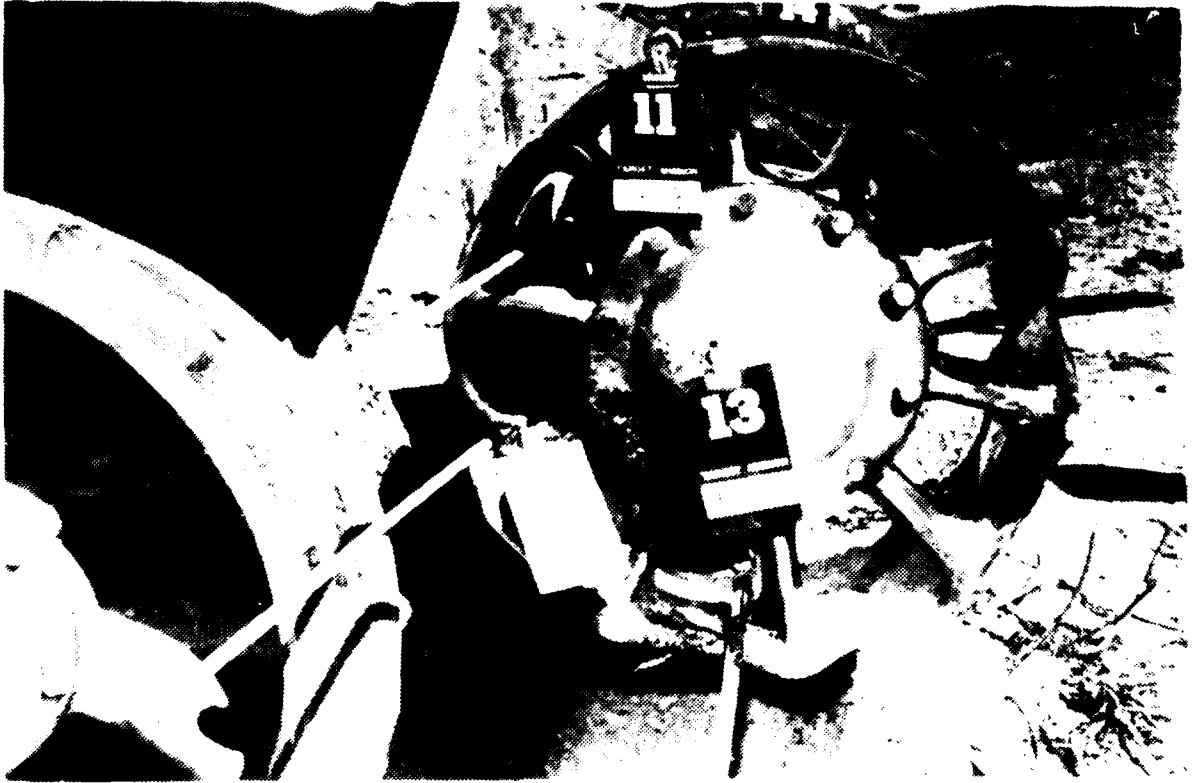


Fig 32. Impacts 11, 12, 13 and 14 Showing
Damage to Right Idler Wheel

Mission 4, Target 18, 8 March 1978

No hits were scored on Target 18 during Mission 4. The target was assessed as retaining 100 percent of its inherent mobility and firepower.

Mission 4, Target 13, 8 March 1978 (See Illustration 5)

This target was impacted by 32 projectiles of which 11 perforated the armored envelope. Of the 11 perforations, Impacts 1, 2, 3 and 4 (Fig. 33) perforated the right rear turret area and entered the fighting compartment. Either of these projectiles, all of which occurred between 0 and .57 seconds into the burst, was capable of behind-the-plate effects resulting in a catastrophic kill. A 100 percent K-Kill was assessed based on damage resulting from impacts 2, 3 and 4. Impacts 9 and 10 (Fig. 34) and 13 (Fig. 35) perforated the engine compartment. A high probability of damage to mobility related components was associated with impacts 9 and 13. The remaining perforations (impacts 11, 12, 14 and 15 (Fig. 36) caused insignificant or no damage behind the plate.

Impacts 21, 22, 23, 24, 29, 30, 31 and 33 caused insignificant mobility related damage as follows:

Impact 21 (Figs. 37 and 38) -- Knocked off one tooth of right track drive sprocket and penetrated the right number four road wheel. A 10 percent loss of function to the drive sprocket was assessed.

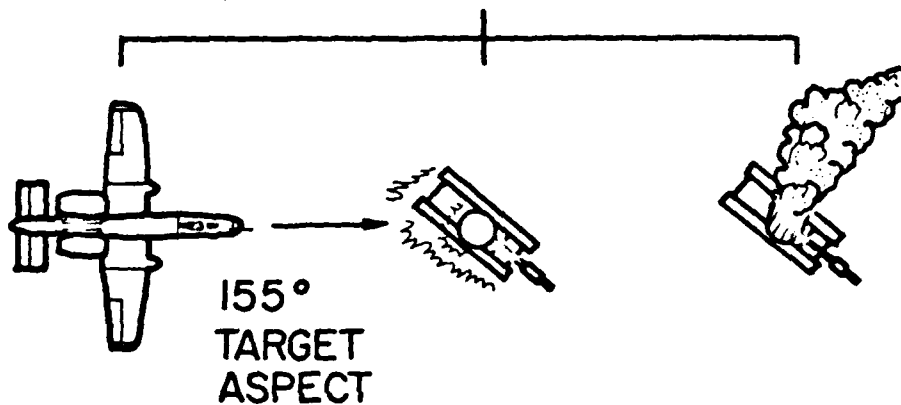
Impacts 22, 23, 24 and 33 (Figs. 37, 39 and 40) -- Penetrated the right number four road wheel hub (Impact 23), split and deformed the outside road wheel (Impact 33), and split the outside road wheel on the opposite side of the wheel from Impact 33 (Impact 22). A 100 percent loss of function to the road wheel was assessed.

Impacts 29, 30 and 31 (Fig. 41) -- Broke out a 10" section of the right number one road wheel with an assessed loss of function of 100 percent.

The target was impacted by 13 other projectiles which caused insignificant damage and made no contribution to the assessed kill.

ILLUSTRATION 5

A-10/GAU-8 LOW ANGLE FIRINGS
VERSUS INDIVIDUAL SOVIET TANKS
(MISSION 4, PASS 2 VS TANK 13)
(8 MARCH 78)



① A/C PARAMETERS

- 373 KNOTS
- 3.87° DIVE ANGLE
- 3321 FT OPEN FIRE
- 2221 FT CEASE FIRE
- 120 RDS FIRED

② GAU-8 WPN EFFECTS

- 120 RDS FIRED
- 33 IMPACTS
- 11 PERFORATIONS
- RATIO
IMPACTS/RDS 0.28
- RATIO
PERFS/IMPACTS 0.33

③ DAMAGE ASSESSMENTS

- K-KILL
- INTERNAL
EXPLOSIONS
AND FIRE
- RESULTING
FROM REAR
TURRET PERFS



Fig 33. Perforations of the Fighting Compartment,
Impacts 1, 2, 3 and 4, Mission 4, Target 13

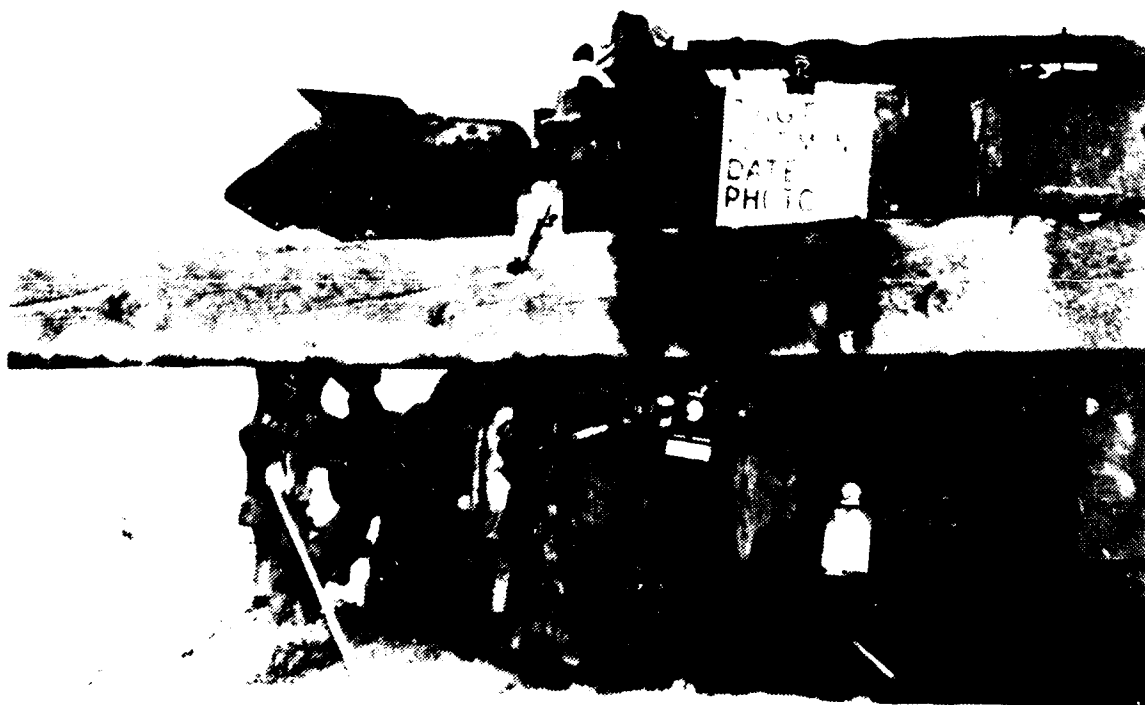


Fig 34. Perforations of the Engine Compartment,
Impacts 9 and 10, Mission 4, Target 13

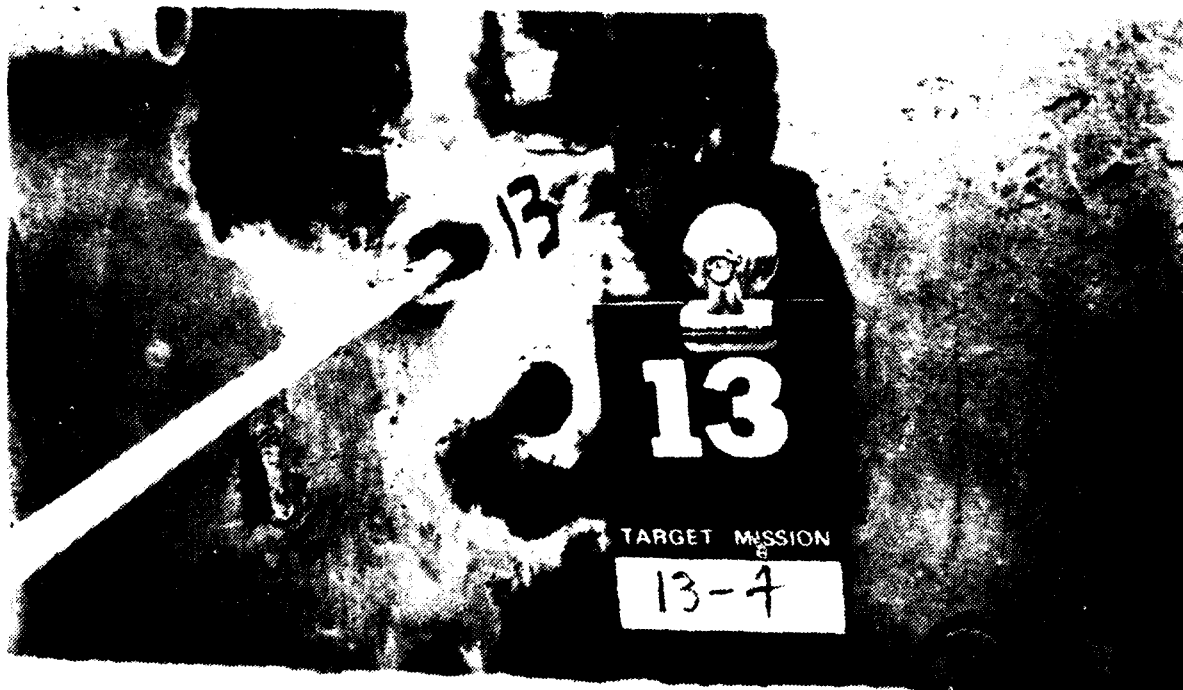


Fig 35. Perforation of the Engine Compartment.
Impact 13, Mission 4, Target 13.

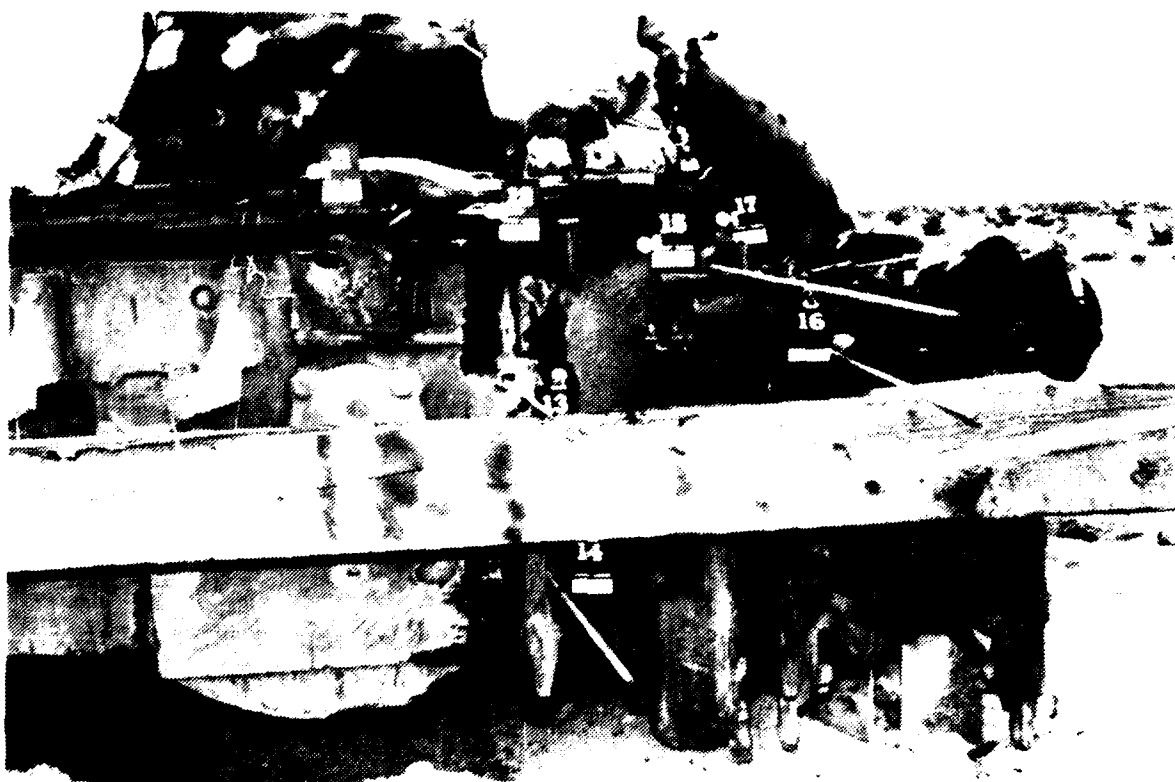


Fig 36. Perforations of the Armored Envelope
Causing Insignificant Damage, Impacts
11, 12, 14 and 15, Mission 4, Target 13

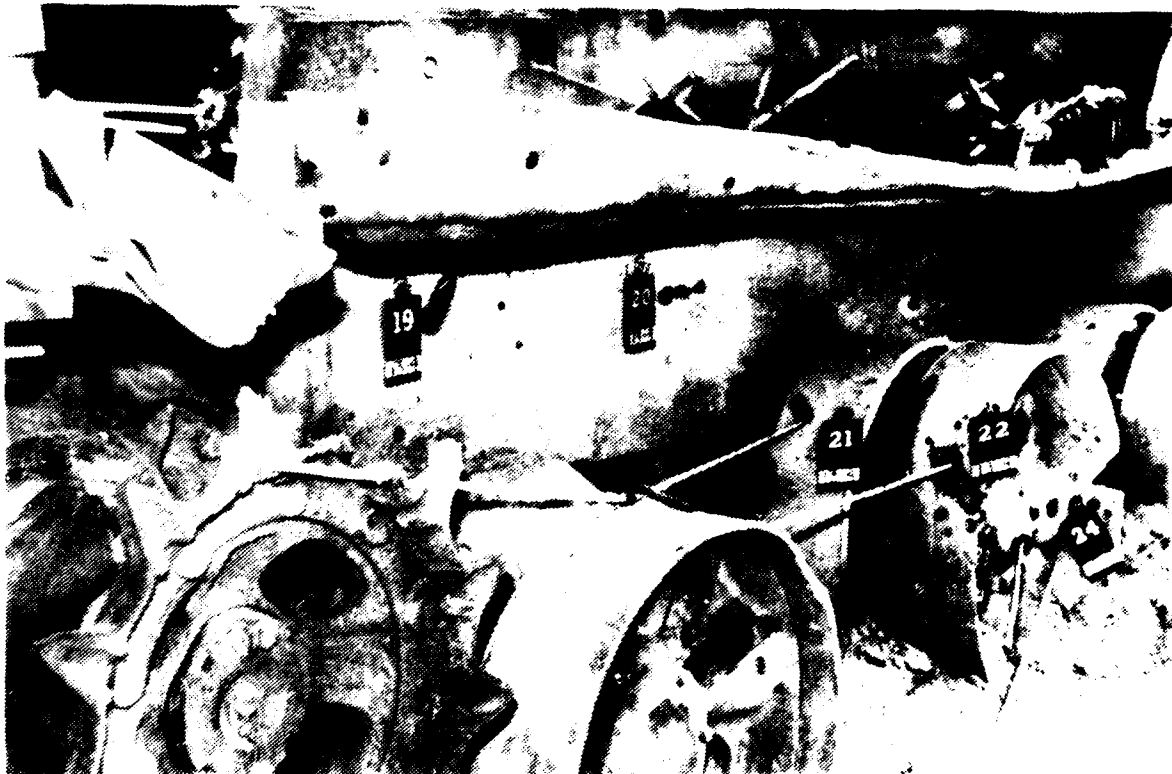


Fig 37. Damage to Right Track Drive Sprocket and Number 4 Roadwheel, Impacts 21, 22, 23 and 24, Mission 4, Target 13



Fig 38. Close-up of Missing Sprocket Tooth,
Impact 21, Mission 4, Target 13



Fig 39. Damage to Right Number 4 Road Wheel,
Impact 23, Mission 4, Target 13



Fig 40. Damage to Right Number 4 Road Wheel,
Impact 33, Mission 4, Target 13

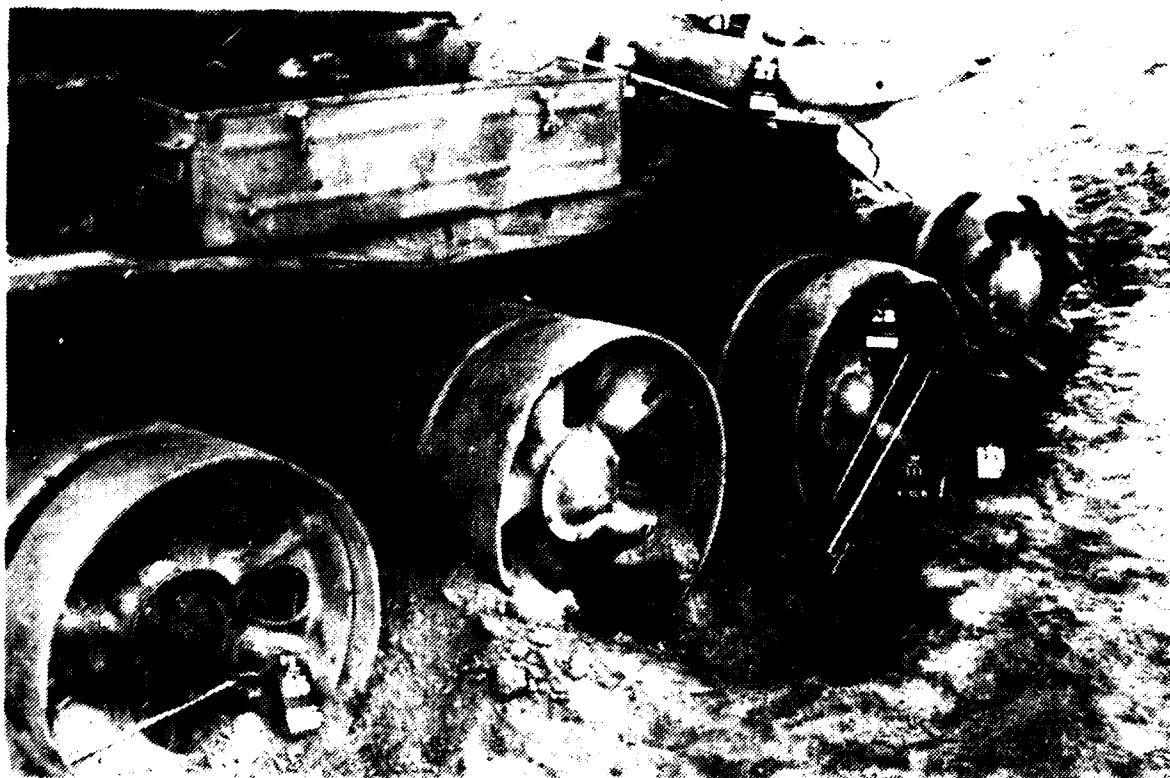


Fig 41. Damage to Right Number 2 Road Wheel,
Impacts 29, 30 and 31, Mission 4,
Target 13

Mission 5, Target 18, 10 March 1978 (See Illustration 6)

This target was hit once on the turret, three times on the upper sloping (glacis) plate, and three times on non-armored components, for a total of seven impacts (Fig. 42).

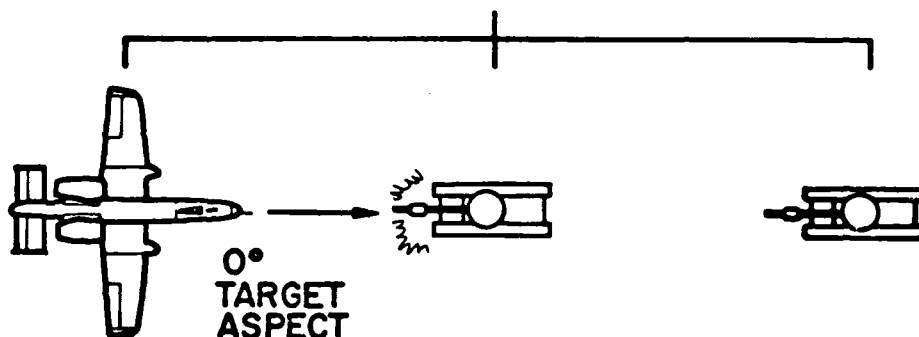
None of the impacts resulted in a perforation. All impacts on armor were at high obliquities which gouged the armor, but with no behind-the-plate effects. Impact 1 against the turret and Impacts 3, 4 and 5 against the upward sloping (glacis) plate are shown close-up in Figs. 43, 44, 45 and 46 respectively. No degradation of firepower was assessed.

Hits 6 and 7 (Fig. 42) impacted the left front fender of the target and the hole characteristics indicated a ground ricochet in both cases. Close inspection of the idler wheel revealed no damage. While the track was not installed the damage assessment indicated that if the track had been installed it would have remained intact with no degradation of mobility.

Hit number 2 was the only potentially significant impact. The characteristics of this hole also indicated a ground ricochet, but one with sufficient stability and velocity to penetrate the idler wheel rim before dissipating against the idler spindle housing flange without further damage (Fig. 47). The track was not installed. Had the track been installed, it would have been impacted first and may or may not have been significantly damaged. While recognizing the possibility of a partial or complete mobility kill due to a broken track, the CDAT, in the absence of on-site evidence to the contrary, elected to assess no degradation in mobility resulting from this hit. This judgment was based on characteristics of the hole and previous CDAT experience with small holes in steel waffle type track.

ILLUSTRATION 6

A-10/GAU-8 LOW ANGLE FIRINGS
VERSUS INDIVIDUAL SOVIET TANKS
(MISSION 5, PASS 1 VS TANK 18)
(10 MARCH 78)



① A/C PARAMETERS¹

- SPEED
- DIVE ANGLE
- OPEN FIRE
- CEASE FIRE
- 165 RDS FIRED

② GAU-8- W/PN EFFECTS

- 165 RDS FIRED
- 7 IMPACTS
- 0 PERFORATIONS
- RATIO
IMPACTS/ RDS 0.04
- RATIO
PERFS/IMPACTS 0.00

③ DAMAGE ASSESSMENT

- NEGLIGIBLE
DAMAGE

¹ NO TSPI DATA WERE AVAILABLE FOR MISSION 5, PASS 1



Fig 42. Location of Strikes, Impacts 1 through 7,
Mission 5, Target 18



Fig 43. Close-up of Impact 1, Mission 5,
Target 18



Fig 44. Close-up of Impact 3, Mission 5,
Target 18



Fig 45. Close-up of Impact 4, Mission 5,
Target 18



fig 46. Close-up of Impact 5, Mission 5,
Target 18



Fig 47. Close-up of Impact 2, Mission 5,
Target 18

V. SUMMARY AND CONCLUSIONS

Working within the framework of the Lot Acceptance Verification Program (LAVP) of the Armaments Directorate, A-10 System Program Office, and on the basis of general cooperation between the Systems and Tactical Air Commands, USAF, pilots of the 66th Fighter Weapons Squadron, Nellis AFB, Nevada, attacked individually sited Soviet T-62 tanks during the period 17 February - 10 March 1978. Two T-62 tanks were used as targets for the tests and were loaded with 90mm TP ammunition, diesel fuel, lubricating oil, and crew mannikins. The purpose of the tests was to evaluate the performance of GAU-8 ammunition when fired from the air under operational conditions and to evaluate its lethality at low dive angles against Soviet tanks. The low altitude attacks were intended to simulate evasion of a radar controlled air defense network. The test philosophy was one of live firing against combat loaded MBTs in order to assess weapon effects and damage on the basis of observed results against actual damaged targets.

The pilots achieved 93 impacts in six out of the total of seven firing passes in the tests. Seventeen of the impacts on the tanks perforated the armored envelopes and contributed in varying degrees to catastrophic damage on the perforated tanks. Seventy-six of the impacts on the tanks failed to perforate, but a significant number of these impacts effected mobility and firepower type damage on five out of the total of seven tanks significantly damaged in the tests. Both the ballistic performance of the GAU-8 ammunition and its lethality must be measured in terms of damage inflicted on realistic targets, and Figure 3 below summarizes the tests in terms of damage inflicted on the combat loaded T-62 targets:

Table IV
A-10/GAU-8 System Damage Analysis
Seven Passes Versus Seven T-62 Tanks

<u>Kill/Damage</u>	<u>Ratio Kills Per Pass</u>	<u>Number Passes at Attack Aspect</u>
K-Kill/Catastrophic Damage	0.43	2 at 180° (Rear) 1 at 155° (Rear)
M-Kill/Mobility Damage	0.14	1 at 90° (Rear)
F-Kill/Firepower Damage	0.00	-----
M & F Kill/Balanced M & F Damage	0.14	1 at 90° (Rt Side)
Insignificant or No Damage	<u>0.00</u>	<u>2 at</u> 0° (Front)
Totals	0.71 Overall	7 at Various Aspects

The table shows that the ratio of catastrophic kills per pass was a substantial 0.43. The ratio of all types of kills per pass, including K, M, F, and M&F kills, was 0.71. The two low angle attacks against frontal aspects of the T-62 tanks resulted in insignificant damage to the targets. In one of the passes, the pilot missed the target and inflicted no damage; in the other, the pilot impacted the target seven times and inflicted insignificant damage. The fronts of the hulls and turrets of Soviet T-62 and other similar tanks present well sloped and thick armor whose main strength is the defeat of kinetic energy projectiles. In low angle passes by aircraft with 30mm AP ammunition against such targets, the probability of a kill from the front is low and depends on (1) synergistic effects on the front track and idler wheels, (2) perforations through the walls of the gun tube, and (3) perforations through vision apertures, hatches, and similar surfaces. The chances of the above effects taking place are increased by short range attacks which raise the number of impacts on target because of the improved accuracy of the gun system at short ranges, and an increase in the number of perforations because of the higher terminal velocities of the projectiles.

The target tanks were arranged systematically in the tests to present certain technically and tactically significant aspects to the attacking aircraft, e.g., front, side, and rear surfaces. Although the firings were conducted at long open fire ranges of up to 4,400 feet, the observed weapon effects and damage were severe on the side and rear surfaces of the hulls and turrets. The shorter range attacks from the front of the tanks during which seven projectiles were placed on target resulted in insignificant damage. The small overall data sample - 7 passes, 6 tanks impacted, 957 rounds fired, 93 impacts, and 17 perforations - makes it difficult to generalize extensively about the performance of the ammunition and the lethality of the projectiles. The test data support a view that the 30mm APIT ammunition is effective against combat loaded Soviet T-62 tanks when fired at low dive angles and moderate to long open fire ranges.

The test data, other similar data, and combat results since the Second World War, point toward the generalization from a technical viewpoint that modern MBTs are susceptible to catastrophic damage from 30mm - 37mm aircraft fired projectiles against side, rear, and top surfaces. The CDAC recommends that future A-10/GAU-8 tests include emphasis on short range attacks against the sides of MBTs to gauge the effectiveness of the ammunition as a catastrophic damage agent.

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